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THE PROBLEM OF ORGANIZATION

THE PROBLEM

THE contemplation of living beings has ever plunged the human mind into a state of perplexity and interrogation. So manifold are the aspects presented to us by the form and behavior of living things and so diverse are the minds which have sought to interpret the phenomena of life that we may at times feel ourselves submerged in a sea of distracting problems, uncorrelated theories and data which, while valuable, are more or less chaotic. From time to time, momentarily realizing that the particular problem which looms immediately before us, mighty and impregnable, is but one of a score or a hundred of equal importance, and that its solution would be for us as merely one sentence of a long story, we give vent to a question which at once epitomizes all of our perplexities and expresses the very heart of what we want to know. We ask, what is an organism? But this question, simple in form, yet all-inclusive, leads us nowhere. It is a blank wall offering no foothold for experimental attack. Should nature present to us no other question than this, she will ever remain a sphinx. For working purposes we must find questions which suggest a program of investigation. The following discussion states no new problem. Nor does it purport to be in any essential matter a new statement of the old problem of the organism. It is at most a restatement of the problem in terms which lay the emphasis at a point where it has been, perhaps, not so commonly put, but where for purposes of investigation I believe it may

to advantage be placed. We will ask, not "what is an organism," but *what is organization?* The first question is too comprehensive and therefore vague and unworkable. The latter question, aiming at the very essence of what we want to know, enables us to turn from the distracting complexity of the entire organism to any observable part of it, the smaller and simpler the better, which exhibits that distinctive characteristic of the whole, *organization*.

A familiar form of anatomical description begins by stating that the morphological unit is the cell. Cells, then, are associated together to form tissues, which enter into the composition of organs. Several organs cooperating in a set of related functions constitute an organ-system. The whole animal, finally, may consist of several such organ-systems. A complete description of structure would lead us to a considerably greater degree of complexity, for we should find units intermediate between certain of those which we have just mentioned. Thus, the kidney as a whole we call an organ. But analysis resolves it, not immediately into tissues, but first into such secondary or lesser organs as renal tubules, renal corpuscles and blood-vessels.

Turning from the morphological to the physiological point of view, we observe a series of units of function precisely corresponding to the series of structural units. It could not be otherwise, for structure is merely the visible expression of function.

Whether we view the structural or the functional aspect of the animal, we see the component units so correlated and coordinated one with another that the result is a harmonious action of the whole in relation to a fairly well-defined set of external conditions. This systematizing of many lesser units into one greater unit is so striking a peculiarity of living things that we call them organisms.

Organization, however, is a peculiarity not merely of the animal or plant as a whole, but likewise, to a considerable degree of minuteness, of its constituent structural units. There are certain things which cells do quite independently of the fact that they belong to any particular tissue or animal. The fundamental processes of metabolism, growth and reproduction are inherent in cells. Obviously, a tissue cell has an organization within itself. So far as my present purpose is concerned, it would not now be profitable to speculate as to how far there may be still other self-contained organizations within and inferior to the cell. A tissue, likewise, has a certain organization within itself. There are certain activities which a tissue performs quite independently of the fact that it is a part of a particular organ or animal. Muscle tissue, removed under appropriate experimental conditions from the animal to which it belongs, exhibits its characteristic activities. The contraction of an excised piece of muscle is, to be sure, merely the resultant of the contractions of its constituent cells. I speak of it as a tissue act rather than a cell act in the sense that it is action of a specialized type—one not exhibited by cells in general but only by such cells as possess those peculiarities characteristic of muscle tissue. A small bit of epithelium transplanted into a foreign locality, or maintained under artificial cultural conditions, may exhibit its peculiar habits of growth. The essential function of an epidermis is to cover outside surface. If a portion of an animal is denuded of epidermis, the remaining epidermis, provided the wound is not too extensive, extends over and covers the exposed deeper tissues. If a small fragment of living ani-

mal material, including some epidermis together with deeper tissue, is isolated under proper conditions, the fragment may become more or less completely covered over by extension of the epidermis. This covering of outside surface by epidermis of uniform thickness and character is distinctly a tissue phenomenon due to a certain organization inherent in the tissue. It is not dependent, at least not necessarily dependent, upon the organization of the animal as a whole. A distinction between tissues and organs can not always be sharply made. However, it is clear that the action of an organ is not necessarily dependent upon the integrity of the animal to which it belongs. A vertebrate heart, under proper conditions of temperature and fluids, will continue its rhythmic action long after removal from the animal. (So, indeed, will an excised strip of its muscular wall.) An excised kidney long retains the capacity for functional activity. Under normal circumstances it is dependent for its oxygen and nutrition upon the animal to which it belongs. But in its organization as a kidney, it seems to be quite independent of the animal as a whole. And finally, there are activities which are distinctly functions of the animal as a whole—the hydra seizing and swallowing a cyclops, a dog following a scent, a cat fighting, a kitten playing. Here we see the animal acting as a unit. Its action is relatively simple and intelligible just as its external form is. But analysis of the action resolves it into a complex of physiological units corresponding to a complex of structures involving perhaps all of the subordinate organizations of the animal.

Comparing the units of these several grades of organization, the cell stands forth with peculiar prominence. It has always appeared so to the biological mind. The fact that every animal part, upon analysis, reduces to cells, the uniformity in size and visible structure of these bodies, make them conspicuous as universal morphological units. The tissue, and even the organ, is ordinarily much less definitely formed and limited, less sharply individualized. The organ-system is obviously a somewhat arbitrarily distinguished unit. In strict morphological sense, at the first step of analysis the whole individual resolves itself directly into organs. The natural tendency, then, is to regard the cell as the essential morphological and physiological unit. In fact, so important does the cell appear that we have been inclined to consider the relation between cell and organ, or even between the cell and the whole individual, to be a direct one rather than one which is indirect by way of such intermediate systems as may exist.

In presenting this familiar sketch of the plan of an organism, I use the word, organization, in its ordinary sense. It is not structure nor is it function. It consists in certain definite and obvious relations of functions, and therefore of structures too. It asserts nothing as to the nature of these relations and it implies nothing as to how they have come to exist. Just here we meet some serious biological problems. What is the nature of those relations which constitute organization? How do they come into being? By what and how is it determined that a group of cells shall be associated together to constitute an epithelium of definite and constant thickness and character? In muscle tissue how does it come about that thousands of cells are substantially alike and capable of operating harmoniously together in response to an effect received from nerves? What is it that affects a mass of tissue of a certain kind in such a way that it assumes the

form and position appropriate to its participation in the tissue complex of an organ? What determines those mutual relations whereby diverse organs operate harmoniously together in the service of the whole?

Our conception of the organization of living things must remain imperfect and incomplete until such questions as these are answered. When they have been answered we may, in the light of our increased knowledge, amplify and perfect our definition of the word, organization. Or, if we prefer, the word may be retained in its present significance as applied to plants and animals, indicating those relations which even now we clearly enough perceive to exist, and we may use some other designation for whatever shall have been found to underlie these relations. I am using the word to designate those conspicuous peculiarities which have led us to call living things organisms. Our problem is to discover upon what this organization rests.

HYPOTHESES

The inquiry as to the nature and underlying basis of the relations which constitute organization meets two alternative answers. According to the one we may regard the constituent elements of any organic system—be it cell, tissue, organ, or the whole individual—as causally independent of one another *so far as their condition of being organized into a system is concerned,* and we may suppose further that no dynamic agent specifically responsible for their organization into a system exists. The fact that the constituent elements of the system do depend upon one another in a variety of ways and that they do stand in diverse definite relations to one another constitutes their organization. But the cause of the organization of the system does not necessarily lie within the various interrelations of the several members of the system, nor in any effects derived from other organic systems. Each element possesses a certain constitution. It exists in a certain physical, that is, non-physiological, environment. (The physical peculiarities of this environment may, however, be to a great extent dependent upon the physiological operation of other organic elements and systems.) It executes activities which are direct functions of its constitution and environment. If these activities take place in such a way as to produce harmonious action of the several members of a group, thus constituting them into a system, such harmony is to be regarded as merely the incidental result of the circumstance that the members are so constituted and so environed. The member is in no way responsible for the fact that its behavior is subserving the needs of the entire organism, and no more is the organism as a whole responsible for the behavior of its elements.

Viewed in this way, the organization of any system results essentially from peculiarities in the constitution of the members of that system, the members being not only independent of one another as regards the fact of their being organized, but likewise independent of any immediately present coordinating agent. Organization, then, is merely something that we read into natural phenomena. It is in itself nothing. Going to the logical conclusions of the matter, it is a name for certain inevitable and purely accidental consequences of the circumstance that atoms or other primordial physical entities possess certain inflexible habits of movement. If we are perplexed by the fact that the total effect of the operation of a subordinate system appears as a more or less important function in the

physiological economy of the whole animal, we need only consider that, had it been otherwise, the "struggle for existence" must have long since made an end of the matter.

An alternative view attributes the harmonious operation of a system to the action of some dynamic agent or energetic complex which exercises general control over the members of the system. These members must be similarly constituted in order that they may properly respond to the controlling agent. The control may be conceived to consist in the action of a superior dynamic agent upon an inferior system, or in some effect of the system as a whole upon its individual members.

It is quite obvious that the activity of one organ does affect the tissues and cells of other organs and that the units of one system are dependent in a variety of ways upon other systems. An epidermal cell is dependent upon the digestive, respiratory, circulatory and excretory systems, and less directly upon the nervous and other systems. There are numerous other relations, perhaps equally important even if less obvious, such as exist between the ductless glands and other organs and tissues in vertebrates. Indeed, it appears likely that we are at present very far from a complete knowledge of the extent to which internal secretions or hormones may serve in the correlations of organs. In ontogeny hormone action may play a rôle of utmost importance as a "mechanism for organic correlation."[1] The nervous control of muscular, secretory and other activities affords what is, in a sense, the most conspicuous instance of control exerted by one part over another part. But while such relations as those involved in nervous control and hormone action may be absolutely essential to the normal operation of the various organs and systems of the animal, it by no means necessarily follows that such relations involve any *general control* of the *organization* of the elements of one organ by the action of another organ. So far as the nervous system is concerned, quite the reverse may be true. An agent which controls certain activities of a group of elements may in no way be responsible for the fact that those elements are capable of responding to its control. The relation of the nervous tissue to the muscle tissue may be exceedingly limited in that it is perhaps only the processes concerned with contracting that are under nervous control. The general organization of the muscle is not, so far as we know, due to nervous control. Professor R. G. Harrison and his co-workers have achieved results of far-reaching importance in demonstrating that the ontogenetic differentiation of muscle tissue is independent of any action of the nervous system. In the fully differentiated muscle tissue exists an organization which renders the tissue capable at any instant of proper response to nervous stimulation. What is it that maintains this organization in the muscle? An answer to the question may be offered by asserting that the histological peculiarities of muscle tissue are due to germinal preformation, and having been so determined and developed, they persist. This may or may not be satisfying. Tissue cells are not structures like stone blocks laboriously carved and immovably cemented in place. They are rather like local eddies in an ever-flowing and ever-changing stream of fluids. Substance which was at one moment a part of the cell passes out and new substance enters. What is it that prevents the local whirl in this unstable stream from

[1] Parker, G. H., 1909, "A Mechanism for Organic Correlation," *American Naturalist*, Vol. 43, April, pp. 212–218.

changing its form? How is it that a million muscle cells remain alike, collectively ready to respond to a nerve impulse? If germinal preformation answers the question, the nervous system is relieved of any responsibility for the maintenance of organization in the muscle tissue. The nervous system exercises occasional instantaneous effects upon the muscle, resulting in one particular kind of activity. So far as this relation is concerned, there is no evidence of general control exerted by nervous tissue over muscle tissue. Even the more or less continuous tonic effect of nerve on muscle does not prove the existence of any control beyond the observable tonic effect itself.

With the case of internal secretions the matter stands much the same. That a substance poured by one gland or tissue of the body into the blood stream may produce most important and specific effects upon other tissues or organs has been demonstrated beyond doubt. The secreted substance may be one in whose absence certain definite abnormal conditions arise, as in the case of the thyroid. Or it may be one whose presence is somehow connected with the perfectly normal development of an organ, as in the relation between gonads and secondary sexual organs. But in all these relations which are established by the transmission of nervous impulses or specific substances from one part of the body to another, we find no answer to the question which we have stated. Upon the contrary, the more of these relations we discover, the more intricate does our problem become, for it is precisely these relations which constitute organization. They are the materials of our problem, not evidence toward its solution.

Any one of these relations is open to either of the two interpretations which I have stated. View the animal, if possible, without the prejudice which arises from the knowledge that it is an organism. View it as if it were a non-living dynamic complex. The nervous system at once loses its paramount importance. It appears as a system coordinate with several other systems. It no more controls other systems than it is controlled by them. True, certain conspicuous events in muscle are conditioned by something that happens in nervous material. But, so far as we can clearly see, it may be equally true that every operation and event in the nervous tissue is conditioned more or less directly by activities going on in other systems or otherwise outside of the nervous system. The nervous tissue appears as a group of elementary organisms of peculiar form, existing in an environment in which they find the materials requisite for their maintenance. They receive more or less intermittent influxes of energy from this environment and, in turn, discharge it in a more or less modified form. In muscle tissue we see another group of elementary beings, muscle cells, whose habitual environment subjects them to certain energetic actions to which they exhibit a fixed type of reaction. And so it is throughout the whole organism. The substance or the energy which is given off by one element as a by-product or a waste product of its activities becomes a peculiarity of the environment in which other elements habitually carry on their existence. It is a vast symbiosis. It is comparable to the relation which exists between the plant life and the animal life of the globe. Green plants need carbon dioxide and give off oxygen. Animals need oxygen and give off carbon dioxide. And so they live successfully together. But would any one venture to propose that the internal organization of

animals is determined and controlled by plants, or that of plants by animals? There is no more ground for asserting that the organization within a subordinate organ of the individual plant or animal is determined and controlled by another organ from which the first receives some form of energy or some substance. It is clear that the secretion of the thyroid affects the integument. In the absence of that secretion the integument becomes altered in character. But it does not become disorganized. Its cellular elements remain organized as integumentary tissue, but with changes in the details of that organization. There is no ground for attributing the fundamental fact that certain cells are organized as integumentary cells to the influence of the thyroid secretion or any other secretion contained in the body fluids.

The whole process of organic development may possibly be described in terms of hormones. If that shall come to pass, a considerable degree of complication will have been added to our conception of the process of ontogeny and our information will have been vastly enlarged. May such an achievement be regarded as bringing us one step nearer our goal of understanding the nature of the organization upon which development rests? Only in the sense that it is one step of an infinite number of steps of that particular kind which separate us from the goal. To discover a mechanics of development in terms of hormones is to bring within our cognizance additional facts of organization. No such description will reveal to us the essence of organization. I do not mean to discredit the search for mechanism. Just so far as mechanism exists we must know about it, for we seek the complete truth about organisms. It is conceivable that practical benefits of inestimable importance may follow from a complete knowledge of organic mechanism. But the nature and origin of mechanism are not to be found by discovering more mechanism.

It appears possible that the development of the lens of the vertebrate eye depends upon some effect proceeding from the optic vesicle. But even if this relation is fully proved, the problem of the development of the lens is by no means solved. The invagination of the ectoderm to form a lens may depend upon contact of the optic vesicle with the ectoderm, or upon the action of a substance given off by the optic vesicle. Any such relation between the two structures is open to either of the two interpretations which are before us. The invagination of the lens ectoderm involves what looks to us like concerted action upon the part of numerous cells. We may suppose that each cell possesses an inherent mechanism which, under the conditions in which the cell normally finds itself, compels the cell to play just that particular part in lens development which it does play. This inherent mechanism depends, we may suppose further, upon germinal preformation which in the last analysis, if this view is carried to its logical consequences, depends upon chance combinations of atoms and the accidents of selection. It is a peculiarity of the environment in which the cells live that at a certain time an effect is produced upon them by a group of underlying cells (assuming the relation between the optic vesicle and the lens to have been proved). It happens that this effect introduces precisely the conditions needed to set going the separate mechanisms in the several cells. Upon this view the organization within the ectodermal layer—its organization as ectoderm and such more or less localized organization within it as renders

it capable of producing lenses—is in no way determined by the action of the optic vesicle. The effect proceeding from the optic vesicle serves merely as the trigger to set off the separate mechanisms of the superficial cells. We may conceive the cells, then, to be absolutely independent of one another in the matter of lens formation. Their concerted action is the purely accidental result of the fact that they suffered simultaneously a change in their environment, that is, the effect derived from the optic cup. This effect merely initiates the development of the lens. Neither the ectodermal organization which causes that development nor the process of development is determined by the optic vesicle. Even if lens development required the continuous action of an effect from the optic vesicle, this view of the relation need in no wise be altered, for that continuous action would constitute merely a persistent feature of the environment appropriate to the operation of the separate mechanisms of the ectodermal cells. It is possible, as some experimental data seem to indicate, that regions of ectoderm remote from those which normally give rise to lenses are capable of producing lenses as a result of the action of transplanted optic vesicles.[2] If this is true, the fact would seem to put considerable strain upon the view just outlined. Nevertheless, it is always possible to buttress up a favorite hypothesis with subsidiary hypotheses. If the main thesis is highly esteemed, often some very complicated accessory hypotheses will be tolerated. I am sure that any such difficulty as the present one—and the experimental work upon embryos has yielded many such—will readily yield to this treatment. I will leave the task for those to whom this conception of organization is the favorite one.

What other interpretation can be put upon this matter of lens formation? The essential feature of the process is the concerted action of ectoderm cells. We may regard this concerted action as due to an agent which immediately exercises general control over the behavior of all the cells concerned. If it is true that the optic vesicle has something to do with the invagination of the lens, it is conceivable that the substance of the optic vesicle is a seat of energy which is somehow brought to bear upon the near superficial ectoderm, with the result that its cells are compelled to execute those changes of form and relative position which are involved in the shaping of a lens. We should have to attribute to the ectoderm cells similarity of structure and an inherent mechanism sufficient to render them capable of responding to the control of the optic vesicle. The expression "concerted action of ectoderm cells" should not convey the impression that every cell behaves precisely like every other. Obviously such can not be the case. The lens invagination is not exactly hemispherical. The changes in form and position of the cells must vary according as whether the cells come to lie nearer the axis or nearer the periphery of the invagination. Upon the first view which we have outlined, the factors which determine the differences in the behavior of the individual cells are contained within the mechanisms of the independently acting cells themselves. Upon the second view, which we are now presenting, the differential factors of lens formation lie outside the group of lens cells. So far as internal conditions are concerned, those cells may be precisely alike.

[2] Lewis, W. H., 1904, "Experimental Studies on the Development of the Eye in Amphibia," *American Journal of Anatomy*, Vol. 3, No. 4, pp. 505–536. See also later papers by the same author.

Upon the first, then, of our two views of lens formation, the lens is determined from within; upon the second view it is determined from without. By the first view we see the lens arising as, in strict sense, a purely accidental resultant effect of the operation of many mechanisms which are essentially independent of one another and independent of any external factor which compels their harmonious behavior. By the second view we conceive of an energy or energy-complex, situated perhaps in the substance of the optic vesicle, exerting itself upon a group of ectoderm cells and thereby coercing them into lens formation. In this case the ectoderm cells may be essentially alike and independent of one another, but they are collectively dependent upon an external controlling agent. The external energy-complex plus suitable ectoderm constitutes the formula for a lens. By transplanting the optic vesicle the first member of the formula may be brought into relation with a region of superficial ectoderm remote from that which normally gives rise to a lens. A lens must result there, as elsewhere, provided that the ectoderm in the newly affected region is not too unlike the normal lens ectoderm.

A group of particles of iron in a magnetic field assumes an orderly configuration under the influence of that field. A rough analogy exists between this phenomenon and the hypothetical relation between a group of ectoderm cells and a lens-determining force-complex originating in the optic vesicle or elsewhere. If, however, we succeed in imagining that each particle, in virtue of certain inherent peculiarities and independently of any agent which immediately controls the behavior of the particles collectively, assumes a certain position, and if we can imagine further that, as the outcome of a chain of entirely fortuitous circumstances in the past history of the particles, their several positions are such as to give the whole group an orderly configuration, we shall have illustrated our first conception of the nature of organization. Another illustration presents itself employing, instead of iron particles, mechanisms of considerable complexity and in so far offering greater similarity to what we see in plants and animals. Suppose that ten clocks, precisely alike in construction, strike the hours in unison. So long as the clocks are similarly affected by temperature, moisture and other external conditions, and so long as their energy holds out, they will continue striking the hours in unison—a tissue of clocks. We can imagine that the air vibrations produced by the striking serve to set off some other mechanism. But the mechanism of each clock is entirely independent of that of all the others. Further, so far as the several clocks themselves are concerned, there is no connection whatever between their striking and the setting off of some other mechanism. The air vibrations (a hormone) which transmit the effect from the clocks are something outside of and distinct from the clocks themselves and the responding mechanism as well. A human observer, noting that the clocks keep the same time and strike in unison, and noting that the initiation of a certain activity in another mechanism depends upon something that the clocks do, applies to these several relations the name, organization.

To illustrate the other conception of organization, we may suppose each of the ten clocks to contain a striking mechanism which, for its operation, requires that the clocks shall be affected by an electro-magnetic field. The clocks do not strike at all, then, until by the action of agents outside of themselves they come within the influ-

ence of such a field. They then strike in unison. We may even suppose that there exists a regulatory arrangement such that, if some clocks are running slow and others fast, the mechanism involved in striking serves automatically to restore the clocks to synchronous action. In this latter illustration the striking of the clocks depends in part upon their like construction. But the action of an electro-magnetic field is another and an essential factor in their concerted behavior. It is an agent entirely outside of the clocks themselves which exercises a general control over their activities.

In the first illustration of the clocks the striking in unison consists, so far as we can see at the moment, in the coincident acts of ten absolutely independent and self-contained mechanisms. In the second case there is immediately present a specific coordinating agent which compels the several mechanisms to united and harmonious action. In the absence of this agent the ten clocks would not strike together—they would not strike at all—nor would they keep time together. Viewing such a group of objects, we should see merely ten distinct mechanisms lacking any coordination into a unit or a whole. These illustrations hold only if not examined below the surface. Any inquiry as to how and why the clocks came to be constructed as they are and, in the first illustration, to be wound up, set together, and so precisely regulated as to keep time exactly together, will greatly complicate matters and will render the appropriateness of the illustration more or less dubious.

In this conception of organization as being dependent upon an agent which exercises general control over the elements which are organized, we are not limited to the idea that the control operates from without the group of elements. In the case of the lens we may equally well imagine that the controlling agent is in the lens ectoderm itself; not, however, as embodied in the separate mechanisms of the several cells, but as something which transcends cell mechanism, pervading, so to speak, the whole region of lens ectoderm. Upon this view a formative effect exerted by the optic vesicle upon the lens may be supposed to consist in a stimulus—merely a signal—which serves to initiate the action of a lens-determining agent in the superficial ectoderm. The development of a lens at places other than where a lens normally develops obviously presents difficulties to this hypothesis. We may think of this internal lens-determining agent as operating either by effects upon the individual cells or by action upon the ectodermal protoplasmic sheet as a whole, regardless of cells. Whitman, in 1893, in his paper on "The Inadequacy of the Cell-Theory of Development"[3] gave us a vivid picture of living substance developing into organic form through the operation of large force complexes which express themselves in thickenings, foldings, and the great variety of form changes seen in embryonic layers, irrespective of the subdivision of these layers into cells. At the present time there is a distinct tendency away from any such broad and relatively simple conception of developmental processes toward those which involve overwhelming multiplicity of determining factors and indefinite minuteness of structural mechanism. The current hypotheses which have had their inception in the Mendelian discovery and in correlated cytological research tend toward exaltation of the importance of the cell and more particularly of the chromosome, if not of yet more minute and less accessible elements into which the chromosome is hopefully to be shattered. Yet I believe that the status of the

[3] *Journal of Morphology*, Vol. 8, pp. 639–658.

chromosome is neither biologically nor philosophically so secure as to warrant us in contemptuously rejecting any hypothesis which fails to bow to the chromosome as the omnipotent ruler of organic form.

The first of our alternative views of organization attributes such harmonious and concerted action as we frequently see within a group of similar structural elements—for example, in a simple epithelium consisting of numerous cells which are structurally and functionally alike—to homogeneity in that complex of factors, internal and external, which affects the several members of the system, one factor being as essential as another, and no one factor being especially responsible for the concerted action exhibited within the system. If any one of these factors be removed, provided that it be not one which is directly essential to the existence of the system, the system immediately affected becomes no less organized, but merely undergoes some change in its organization. This change may be one which interferes with the operation of some larger system and perhaps results in the downfall of the whole organism. In such a disaster we see the selective action of "Nature" tending toward the firmer establishment of harmoniously and advantageously operating systems. A certain condition may be essential to the existence of a system, yet in no way responsible for the peculiarities of that system. Oxygen is essential to the existence of a dog, but oxygen is not responsible for the fact that certain living substance is organized as a dog and not as a cat.

In general, then, the first alternative asserts that organized form arises ontogenetically, and is maintained, by the operation of a multiplicity of factors which, for each particular of that form, are coordinate in rank and are associated together just as they are, not by any immediately present and directly operative necessity, but only indirectly through those several necessities which have arisen from circumstances in the past history of the genetic series. When these factors are associated into a homogeneous complex, the resulting type of organization is such as we see in a tissue whose numerous cells are alike in histological differentiation. The shaping of tissues into organs implies a precisely corresponding departure from homogeneity in the complex of factors concerned. The modification or disappearance of any one or several of these factors is not necessarily followed by loss of organization, but only by change in the relations which constitute organization.

The second alternative, while admitting that organization must involve a multiplicity of factors, asserts that amongst these is one factor, or a group of factors, of dominant importance. This dominant factor may conceivably determine structural uniformity and concerted action even when the other factors affecting the system constitute a complex which is not exactly homogeneous. Upon the other hand, we can imagine that the operation of a localized dominant factor in a system otherwise marked by perfect homogeneity of conditions produces the differentiation of a portion of that system into a system of higher order, as when a region of a germ-layer is modified into an embryonic organ. With the removal of the dominant agent, all other factors remaining the same, organization of a certain grade completely disappears, although organizations of lower order may remain. A case which conceivably may prove to be an illustration of this hypothesis is afforded by the headless fragment of worm which, while remaining alive for a considerable time, does not regenerate. The living fragment exhibits organizations of the various grades corre-

sponding to organs, tissues and cells. But the agent which dominates these lower organizations and produces the organization into a whole individual has somehow disappeared.

The first view we may conveniently designate as the theory of autonomous elements, understanding that this autonomy does not preclude the possibility that the environment in which each element lives may depend in a great variety of ways upon the operation of other systems. The second view we may call the theory of controlled elements or the theory of dominance, referring to the existence of specific agents which dominate and coordinate the form and behavior of structural elements.

The problem of organization in the form in which I have here stated it has no definite relation to that problem of ontogeny whose alternative and opposed answers have from time to time and with ever shifting significances borne the names preformation (or evolution) and epigenesis. The theory of autonomous elements associates itself very consistently with the idea of a considerable degree of rigid germinal preformation—mosaic development. Nevertheless, a scheme of development which is to the fullest possible extent epigenetic may be thought of as depending essentially upon the ever-changing environment of each individual element, the orderly series of successively determined stages proceeding in the total absence of specific form-determining agents exercising immediate control over groups of elements. The theory of dominance may likewise be consistently linked with either conception of the mode of development. Let it be assumed that the harmonious operation of any ontogenetic system, such as the concerted action of the entoderm cells in gastrulation, be due to the presence of an agent which coerces the elements of the system into that particular form of behavior, even in spite of some differences which may exist amongst those elements and in spite of some degree of inequality in their several environments—an agent in whose absence there would be no concerted action at all. We then have our choice of these two alternatives. We may attribute the existence and timely operation of the control agent directly to some peculiarity of the germ—preformation; or we may suppose it to arise as a function of the preceding stages in development, being thus only indirectly related to the original germ organization—the epigenetic view.

Neither does the line between our two conceptions of the nature of organization coincide with the line separating those two groups of theories known as mechanistic and vitalistic. This statement can the more confidently be made in view of the fact that there is serious disagreement as to where the latter line really lies. The theory of autonomous elements leads almost necessarily to a mechanistic view of the organism. Factors which are in any sense to be regarded as vitalistic could scarcely be introduced save by actual violence. The theory of dominance, however, affords ample latitude for the extremes of these two groups of opposed philosophical attitudes. If it is possible to imagine that the harmonious action of a system is the resultant effect of the coincident operation of the mechanisms of its autonomous elements, it is equally possible to imagine that mechanisms have arisen on a larger scale, not confined within the limits of a single element, but embracing groups of elements. To think of such a larger mechanism operating through or by means of the elements embraced within its scope, or operating within the substance of a group of elements irrespective of its subdivision into elements, gives us the picture of a

system whose harmonious operation depends upon an agent which dominates all the elements or all the substance within the system. The lesser mechanism of the autonomous element in the one hypothesis and the greater control mechanism of the other hypothesis may equally well be regarded, if one is philosophically so disposed, as being the marvelous outcome of the accidental conspiracy between molecular structure and a selectively acting environment. Upon the other hand, a living being in which extensive groups of elements, physically more or less distinct and even heterogeneous in character, are in a large way dominated by agents which mold form and direct action, offers to the vitalist, of whatever type, a realm in which non-physical, ultra-physical or psychic factors and forces may be created and set going to the limit of his bent.

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(*To be concluded*)

THE GROWTH OF CHILDREN

PREVIOUS investigations have shown that the rate of growth of the body, measured by weight and stature, increases very rapidly until the fifth month of fetal life. From that time on the rate of growth decreases, first rapidly, then more slowly until about four years before the age of puberty. During adolescence the rate of growth is considerably accelerated, and decreases again rapidly after sexual maturity has been reached. Thus the curve of growth represents a line which possesses a very high maximum at about the fifth month of fetal life. It decreases rapidly, and has a second, although much lower maximum shortly before sexual maturity is reached, and not long afterwards reaches the zero point.

The bulk of the body of girls and boys is approximately equal until the period of adolescence. Since this sets in much earlier in the female than in the male, the concomitant acceleration also sets in at an earlier time, with the result that for a few years girls are larger than boys.

The periods of most active growth of the various parts of the body differ considerably. Nevertheless, it would seem that the characteristics of the curve of growth as here outlined are repeated in many if not in all organs and parts of the body. For instance, although the head reaches nearly its full size at an early time, so that its rate of growth shows a much more rapid decrease with age than that of the bulk of the body, there is a slight acceleration of growth during the period of adolescence.

It might seem, judging from the data just mentioned, that the difference between the sexes does not develop until the period of adolescence; but a study of the eruption of the teeth which I made a number of years ago, and the more recent interesting investigations by Rotch and Pryor on the ossification of the carpus, show that the difference in physiological development between the two sexes begins at a very early time, and that in the fifth year it has already reached a value of more than a year and a half.

I give here a tabular statement of the available observations:

	Age in Years		Difference
	Boys	Girls	
Ossification of scaphoid	5.8	4.2	—1.6
Ossification of trapezoid	6.2	4.2	—2.0
Eruption of inner permanent incisors	7.5	7.0	—0.5
Eruption of outer permanent incisors	9.5	8.9	—0.6
Eruption of bicuspids	9.8	9.0	—0.8
Minimum increase of annual growth	10.3	8.2	—2.1
Eruption of canines	11.2	11.3	+0.1
Maximum increase of annual growth	13.2	11.2	—2.0
Eruption of second molars	13.2	12.8	—0.4
Maximum variability of stature	14.8	12.4	—2.4

These data are not very accurate and must be considered a first approximation only.

When we remember that growth depends upon physiological development, it will be recognized that we must not compare the stature of girls of a certain age with that of boys of the same age, but that from the fourth year on a girl of a certain age should be com-